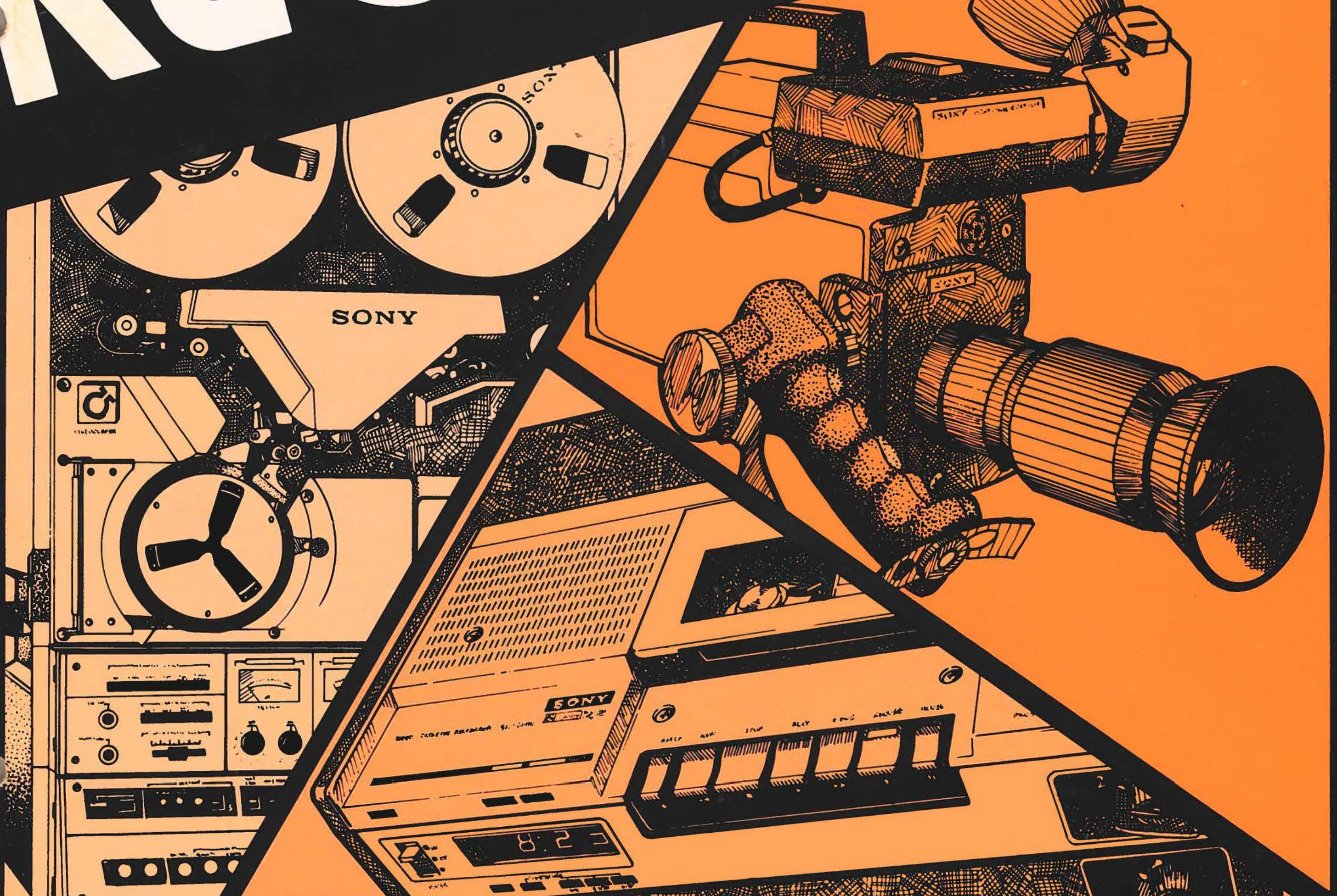
SONY BASIC VIDEO RECORDING COURSE

BOOKLET #2

VIDEO RECORDING



SONY®

BASIC VIDEO RECORDING COURSE

BOOKLET 2

VIDEO RECORDING

Introduction

This lesson deals with basic considerations for the magnetic recording of video signals. To put things in perspective we will briefly review some fundamental aspects of the video signal. Signal processing of the video signal in preparation for recording will then be presented. The latter gives a better idea of actual bandwidth requirements so that writing-speed needs can be predicted.

1. TV SIGNAL REVIEW

The TV signal has been developed with the idea of taking advantage of the limits of human vision so that the minimum amount of information need be transmitted and yet provide a continuous and satisfactory moving image of the scene before the camera. Basic among these limits is the sort of image lag called persistance of vision wherein pictures presented at a sufficiently high repetition rate cease to flicker and become uniform. The other major aspect is visual acuity or the ability to resolve small objects in the picture.

Our system is based upon what the average human observer is capable of resolving when placed at a distance of eight times the picture height from the screen. At this distance we can resolve alternate black and white line patterns consisting of 330 to 350 parallel lines.

In considering vertical resolution (horizontal lines stacked one above the other), we have to consider the fact that the raster itself is made of horizontal lines, and not all will be fully utilized in displaying horizontal line patterns. Some will fall between the lines or off to the top or bottom. Tests with human observers as well as mathematical analysis have developed a utilization ratio of approximately 0.7. That is, 0.7 of the total lines in the raster contribute to vertical resolution. Thus the raster should contain about 337/0.7 lines or 483 lines. This is for the visible part of the picture only and about 8% is needed for vertical blanking so that the total number of raster lines comes to about 483/1 – 0.08 = 525 lines.

Interlace. To be above the flicker rate, pictures should be repeated above about 40 times per second, but the rate depends upon brightness. It was decided at the outset that the picture rate should be tied down to power-line frequency so that the effects of power line hum in the picture would at least be stationary. But if 60 Hz is chosen as the picture rate, the line rate for a 525 line raster would be 60 Hz x 525 or 31.5 kHz and the bandwidth needed to provide 330 line resolution horizontally would exceed 8 MHz.

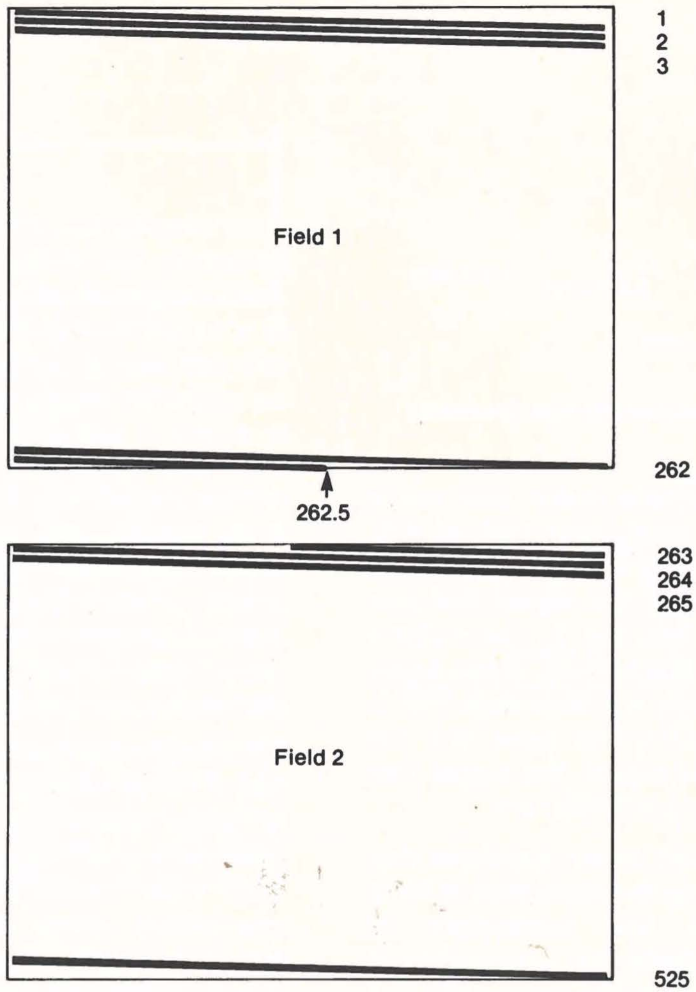


Fig. 1. Interlaced fields.

To counter this enormous bandwidth requirement it was decided to establish the picture rate at 30 Hz and remove the flicker-perception problem by presenting the raster in two halves of 525/2 = 262.5 lines each at the rate of 60 Hz. Thus, half the picture, called a *field*, is made of 262.5 lines in 1/60th of a second, scanned from top to bottom. The next field, starting in the center of its top line and tracing between the lines of the preceding field, completes the next 262.5 lines to make the full 525 line picture, called a *frame*. See Fig. 1. The *frame rate* is 30 Hz; the *field rate* is 60 Hz.

Now for some quick numbers to determine approximate video bandwidth. The line rate is now 262.5 x 60 Hz or 15.75 kHz. If we are to resolve 330 vertical lines in the picture what kind of bandwidth do we need? First of all, to express vertical and horizontal resolution in the same terms we have to take into account the fact that the picture is wider than it is high. The *aspect ratio* is 4:3. Thus 337 lines cover only 3/4 of picture width and we should multiply by 4/3 to get the total number of lines across the picture. Thus 337x 4/3 = 449. The duration of the visible line is 1/15.75 kHz = 63.5 μsec minus 10.2 μsec for horizontal blanking or 53.3 μsec.

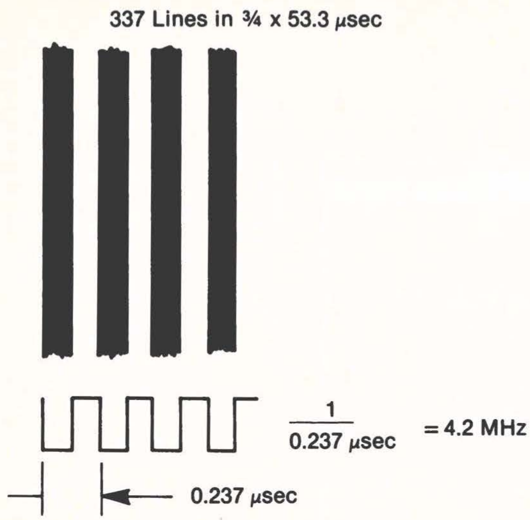


Fig. 2. Relation between resolution and video bandwidth.

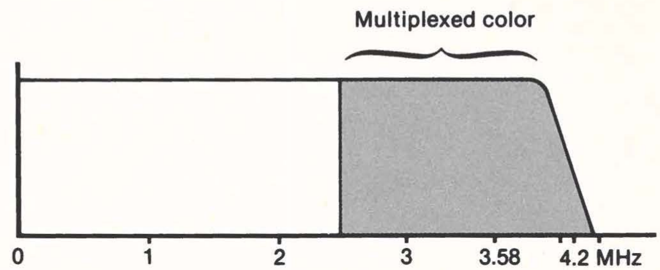


Fig. 3. Video passband.

Now to draw 449 alternate black and white lines in 53.3 μsec we must take half of 449, 224.5 and divide it into 53.3 μsec. This yields 0.237 μsec as the period of the signal that produces the line pattern. See Fig. 2. The reciprocal of 0.237 μsec is 4.2 MHz. Thus, video bandwidth for full resolution is 4.2 MHz. See Fig. 3. This bandwidth is required to pass the full brightness or luminance signal, the signal that produces the black-and-white picture.

Factor 80. A rule of thumb in our business that relates resolution in lines to bandwidth in MHz is the *factor 80.* To find bandwidth requirements in MHz, divide the resolution in lines by 80. Thus 320 lines divided by 80 = 4 MHz. Conversely, multiply the bandwidth in MHz by 80 to find resolution in lines.

This rule is not precise, and at the time of this writing a firm rule for determining resolution has not been agreed upon. In many cases resolution is judged by the visual appearance of the vertical wedges in a test pattern. Depending on observer, contrast ratio etc., this process tends to produce higher resolution figures.

Color Bandwidth Requirements. Visual acuity in color is surprisingly poor. As an example, the San Francisco Golden Gate bridge is painted a sort of dark red—the whole bridge, cables and all. But if you look at the bridge from a distance, say from the Bay Bridge, the towers and roadway look red, but the cables simply look black. The reason is that small picture details are resolved as variations in luminance (brightness only). In Nelson's* time, ships' signal flags were divided into two classifications: near signals, consisting of colored flags; and far signals consisting of black geometric shapes (balls, squares, etc.).

To complicate matters, visual acuity is not the same for all colors. We see all hues in relatively large areas, but as these areas become smaller we can resolve orange and cyan better that other hues, and finally at some point everything turns into variations in relative brightness only. If we talk directly in terms of video bandwidth requirements it works out that we are satisfied with all hues up to a bandwidth of about 600 kHz, orange and cyan to about 1.2 MHz and brightness to about 4.2 MHz. In effect, color TV is like a kid's coloring book. The details are furnished by the luminance outlines and relatively large areas are filled in with sort of blunt crayons (slightly sharper crayons for orange and cyan).

To squeeze the color signal into the existing video passband, it is multiplexed to share the top end of the passband with luminance signals. A subcarrier, chosen to be as high as possible but low enough to permit the upper sideband of a 600 kHz AM color signal has been selected (4.2 MHz − 0.6 MHz = 3.6 MHz). The actual color subcarrier is 3.579545 MHz for reasons that will be reviewed shortly.

*British Admiral Nelson, victor in the famous sea battle off Cape Trafalgar in 1805.

We know that all hues can be reproduced from three primaries. In our system the primaries are red, green and blue. To maintain compatibility with existing black-and-white sets at the time of color introduction, it was decided to transmit the luminance signal (designated the Y signal) and the color signals in terms of color-difference signals R-Y, B-Y, and G-Y. Furthermore, one of these can always be developed from the other two. Thus it is necessary to transmit only two color-difference signals. In one of the prototype systems R-Y and B-Y were selected. They were conducted by means of two-phase modulation. That is, R-Y and B-Y amplitude-modulate the same carrier but the modulators are driven with subcarrier signals 90° apart in phase. The outputs of the modulators are added so that the resultant can vary between 0 and 360° depending on the instantaneous amplitude of R-Y and B-Y. See Fig. 4(a).

Shortly before the acceptance of the NTSC system by the FCC, it was decided to alter the modulation axis 33° as shown in Fig. 4(b). This makes one axis conform to the orange-cyan axis. It is called the *I signal* and occupies about 1.2 MHz of spectrum space. The narrower *"Q" signal* at 90° to the I axis is roughly magenta-green. The Q signal is band limited to 600 kHz. Thus, from 0 to 600 kHz, all colors can be reclaimed. By adjusting the demodulation axis in the receiver, it is possible to demodulate R-Y and B-Y directly. This is the case, with minor variations, in all modern receivers. Between 600 kHz and 1.2 MHz only orange and cyan can be reclaimed. Thus in relatively small areas of the picture the crayon fill-in comes from orange or cyan crayons only. Note that the I signal from 600 kHz to 1.2 MHz is lower sideband only.

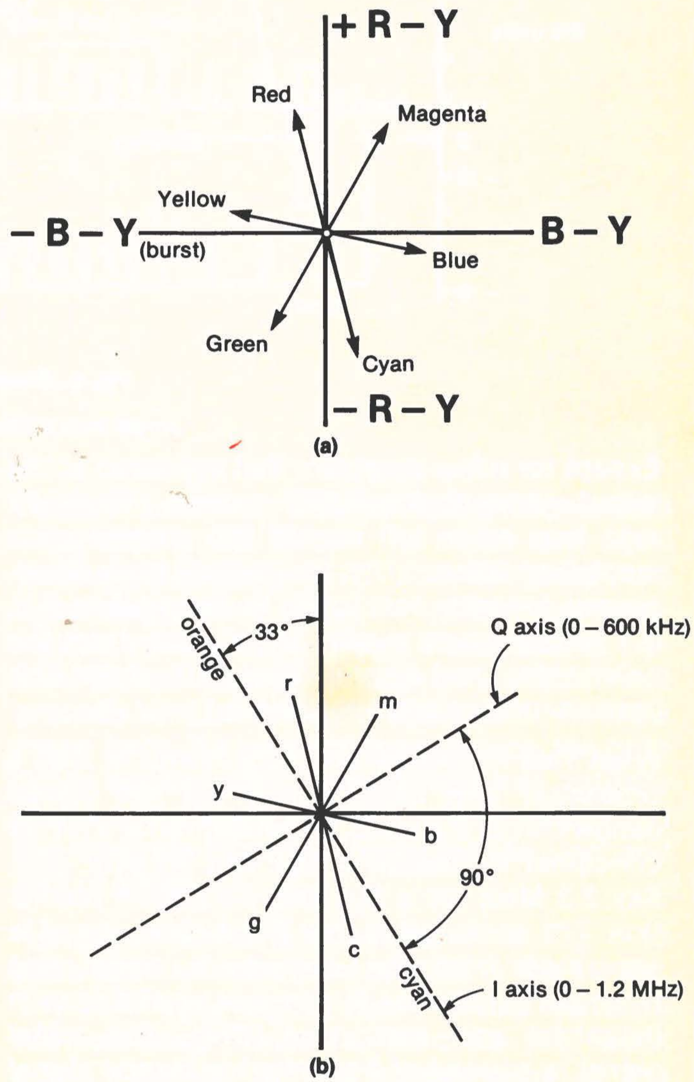


Fig. 4. Color modulation axes.

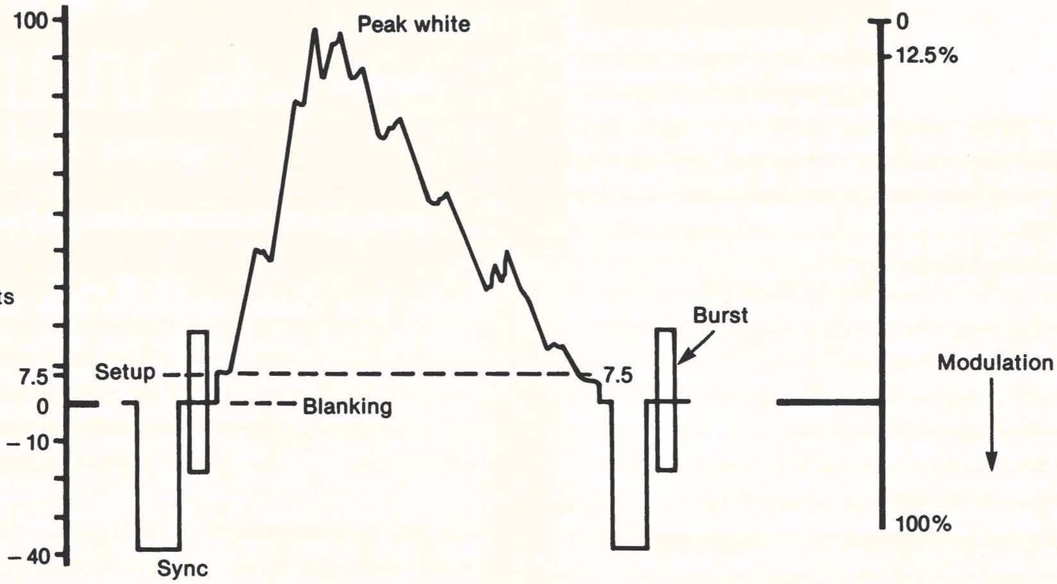


Fig. 5. Composite video signal.

Except for a few receivers that appeared at the introduction of the NTSC system (1954), TV sets that make full use of the greater color resolution afforded by the I signal have disappeared. Industry practice is to demodulate R-Y, B-Y (and in some cases G-Y) directly from the color signal and a color bandwidth of 500 kHz (less in many cases) is achieved.

What this means in practical terms is that a broadcast VTR must record the full overall bandwidth of 4.2 MHz. A monochrome VTR for consumer or industrial use can do with less. Say 3.2 MHz for a 260 line horizontal resolution. The same holds true if the color signal is separated from the composite signal and recorded separately. This is just what's done in industrial and consumer VTRs. The color signal is separated from the luminance signal and recorded separately. It is heterodyned down from 3.58 MHz to a new center frequency in the 600 kHz range and recorded at the low end of the overall recorder bandwidth. Color resolution in this system ranges between 450 and 500 kHz.

Composite Video. Thirty percent of the peak-to-peak composite video signal is reserved for timing signals, the synchronizing pulses that trigger both horizontal and vertical retrace. In broadcast transmission, black represents maximum modulation (100% at the sync tips). See Fig. 5. The remaining 70% is reserved for brightness variations, minus 7.5% of setup (above the blanking level) and about 12.5% down from peak white. The latter is maintained for broadcast purposes to maintain sufficient channel carrier during white peaks (maximum downward modulation) for the intercarrier sound system to operate. (Loss of carrier during white peaks is a cause of intercarrier buzz.)

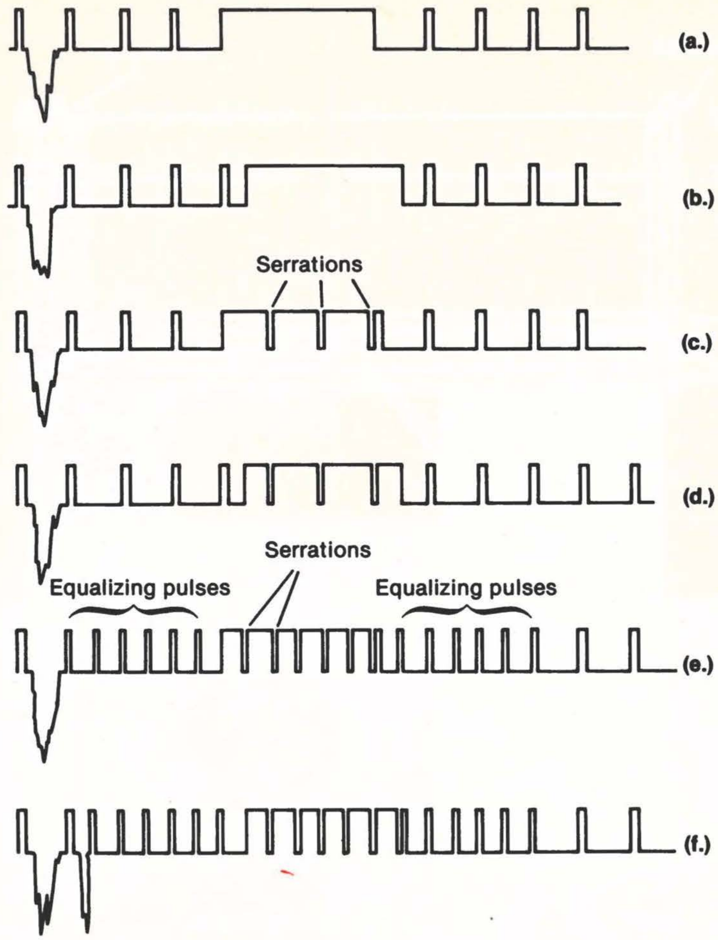


Fig. 6. Evolution of vertical sync signal.

The only difference between horizontal and vertical sync is relative time duration. Horizontal sync is about 4.76 μsec long and vertical is three horizontal lines in duration. Fig. 6 gives a quick derivation of the vertical sync signal and its adjacent timing signals. Figures 6(a) and (b) shows the three-line vertical sync signal for the first and second fields in the interlace system. Note that vertical sync for field two starts midway between two sync pulses.

To keep the horizontal oscillator in the TV set in sync during the vertical sync interval, *serrations* are added to the 3 line vertical sync pulse as shown in (c) and (d) of the figure. The horizontal oscillator in the TV set continues to trigger on the positive-going excursions of the serrations. The problem now remains that vertical sync pulses for the odd and even fields do not look the same, and will provide two different rising slopes when they go through the vertical integrator in the TV set. To make both sync pulses appear alike to the sync integrator, the *equalizing pulses* are added at half line intervals as shown as (e) and (f). These twelve narrow pulses added to the three lines that precede vertical sync and the three that follow make both the vertical sync pulses for both fields appear alike, even though one actually starts at the beginning of a horizontal line and the other starts midway between the start and end of a line.

Horizontal blanking is as shown in Fig. 5 to allow time for horizontal retrace in the TV set. The color sync signal, *burst,* is also transmitted following horizontal sync on the "back porch" formed by the trailing edge of the blanking signal.

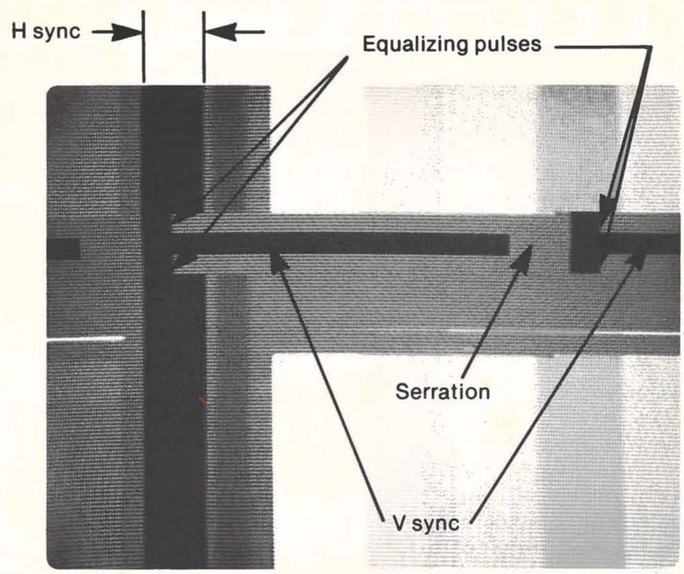
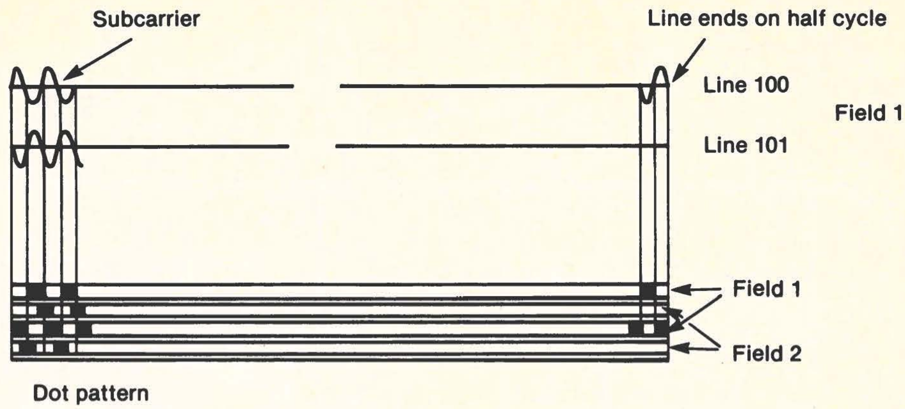


Fig. 7. Cross pulse-monitor.

Vertical blanking is quite long—21 horizontal lines. The first nine lines are occupied with leading equalizing pulses, vertical sync and trailing equalizing pulses. The remainder are available for a number of auxiliary functions. At present VITS (Vertical Interval Test Signal) and VIRS (Vertical Interval Reference Signal) are transmitted on lines 18 and 19. Use of the remainder of the vertical blanking interval for broadcast applications requires action by the FCC, and several groups have petitioned FCC for the use of special purpose signals such as digitized subtitle signals for the deaf. The remainder of the vertical interval can be used for in-house coding, such as frame identification for editing purposes, provided these signals are removed prior to broadcast.

Fig. 7 shows how to relate the hammerhead pattern seen in the vertical blanking period. This display is produced by a cross-pulse monitor.

Color Subcarrier Frequency. An earlier discussion showed that the color subcarrier must be placed about 600 kHz below the upper end of the video passband to allow room for the upper color sideband. The choice of the precise frequency included other considerations. Of prime importance was the appearance of the color subcarrier signal on monochrome receivers (which in those days had full 4 MHz bandwidth). To minimize the visual effects (CW interference causes lines in the picture) it was decided that the line pattern should be stationary and cross the picture at 45° from the horizontal. (Visual acuity is greater for horizontal or vertical lines.) This can be achieved by making the subcarrier frequency an odd multiple of half the horizontal line frequency. In that case, alternate lines in the same field have the subcarrier 180° out of phase. (The line ends at half a subcarrier cycle.) Because of the odd number of lines in the raster, the interlaced



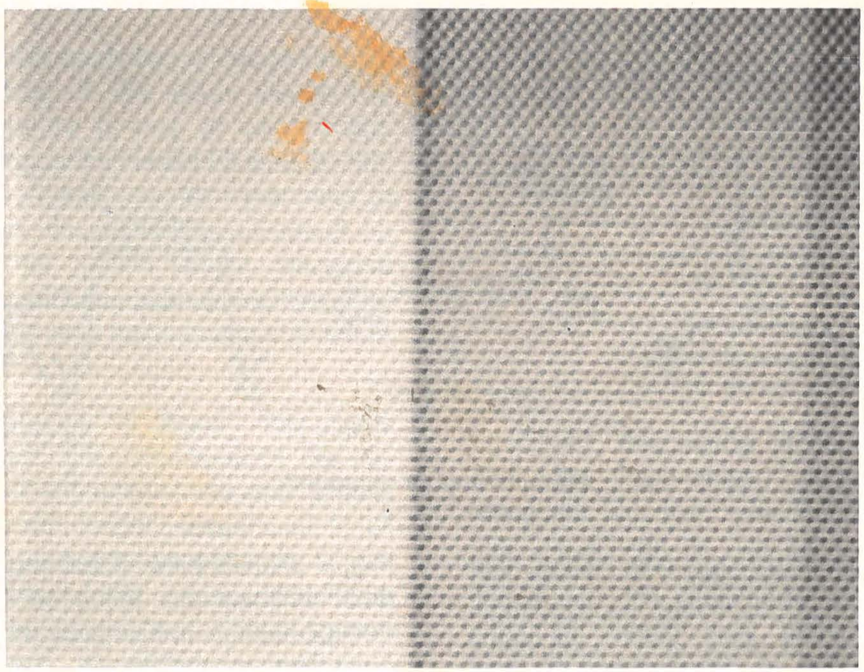


Fig. 8. Interlaced dot pattern caused by subcarrier signal.

field has a 1/4 cycle shift as shown in Fig. 8. This pattern of dots caused by cycles of subcarrier signal is least noticeable visually.

One of the results of this system, that has become important recently in connection with color editing, is that it takes two frames (four fields) for the color signal to get back where it started with regard to sync. Thus, there are four fields in the complete color picture.

A final consideration was the beat between the color signal and the sound carrier. To make this beat stationary and least noticeable, it was decided to alter the subcarrier and the scanning frequencies somewhat. The final value for the subcarrier signal is 3.579545 MHz and horizontal sync is 2/455 times this value or 15.734 kHz. Vertical sync is no longer 60 Hz but 59.94 Hz.

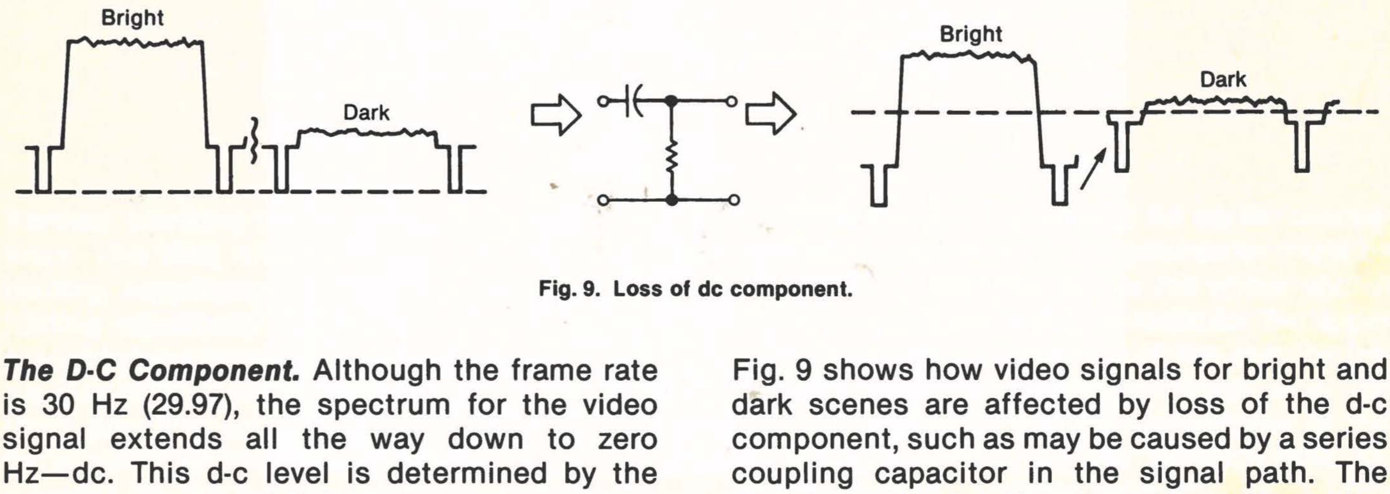


Fig. 9. Loss of dc component.

The D-C Component. Although the frame rate is 30 Hz (29.97), the spectrum for the video signal extends all the way down to zero Hz—dc. This d-c level is determined by the average amount of light entering the camera lens and changes slowly as picture content changes or cameras are aimed in different directions. Loss of the d-c component results in a reproduced picture of constant average brightness, and annoying picture errors. For example, a close up of a performer in a dark suit may reveal shading due to natural reflections on the material. If the camera switches to a wide angle shot that includes a predominantly bright backdrop the dark part of the performer's suit sinks below blanking and becomes a featureless black blob.

Fig. 9 shows how video signals for bright and dark scenes are affected by loss of the d-c component, such as may be caused by a series coupling capacitor in the signal path. The signal resolves itself so that the average value lines up with zero or whatever d-c voltage is found at the right of the coupling capacitor. Note that sync tips are no longer lined up at a constant level.

Loss of the d-c component can be corrected, however, because it was originally related to sync and blanking. Thus, a clamp that ties sync tips to zero acts to "restore" the d-c component. The clamp reference need not be zero but can be any d-c voltage, such as the bias voltage on a picture tube.

2. RECORDING THE TV SIGNAL

When we compare the problem of recording an audio signal with that of the video signal the first obvious difference is one of bandwidth. The audio signal ranges between 20 and 20,000 Hz, while the video signal ranges from zero to 4.2 MHz. In addition, phase response must remain linear over this entire range, because variations in phase shift result in waveform distortion that produces very noticeable effects in the picture.

The techniques applied to audio recorders begin to fall apart for video because of the extreme range over which amplitude and phase response must remain linear. Equalization of the playback signal over a range of some 17 octaves from 30 Hz to 4 MHz would require a boost in low frequency signals of 102 dB based on the 6-dB per-octave rise in playback output voltage versus frequency. Such equalization runs into problems imposed by the extremes of recording—noise at the low end and saturation at the high end. To cut down the octave range of the TV signal, some form of modulation can be used, which places the entire video signal at some other point in the spectrum. For example, if amplitude modulation were employed using a carrier frequency of 10 MHz, the sidebands resulting from a 4 MHz signal would appear at 10 ± 4 MHz. See Fig. 10. This results in the total signal occupying a band between 6 and 14 MHz, less than 2 octaves.

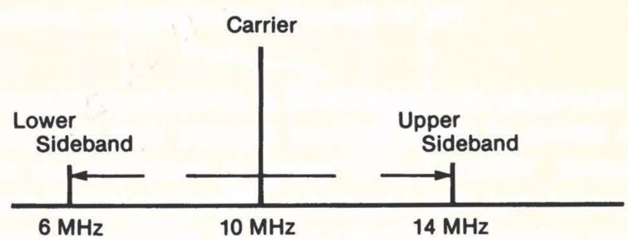


Fig. 10. Amplitude modulation.

However, amplitude modulation is not attractive for high-speed video tape recorders because the machine itself acts to modulate the amplitude of the signal. It does so when the revolving heads stray off the tracks due to microscopic mechanical differences between machines. The effects of dust particles or other debris on the tape acts to lift tape away from the heads causing a momentary drop in signal level called a dropout. This is another form of unwanted amplitude modulation.

Frequency Modulation. The modulation method adopted for video tape recorders is frequency modulation. Long used in instrumentation recorders to record slowly varying signals, FM has no low frequency limit because each frequency represents a given voltage level. Furthermore, the system can be made to ignore the amplitude variations that can not be ruled out in machine playback.

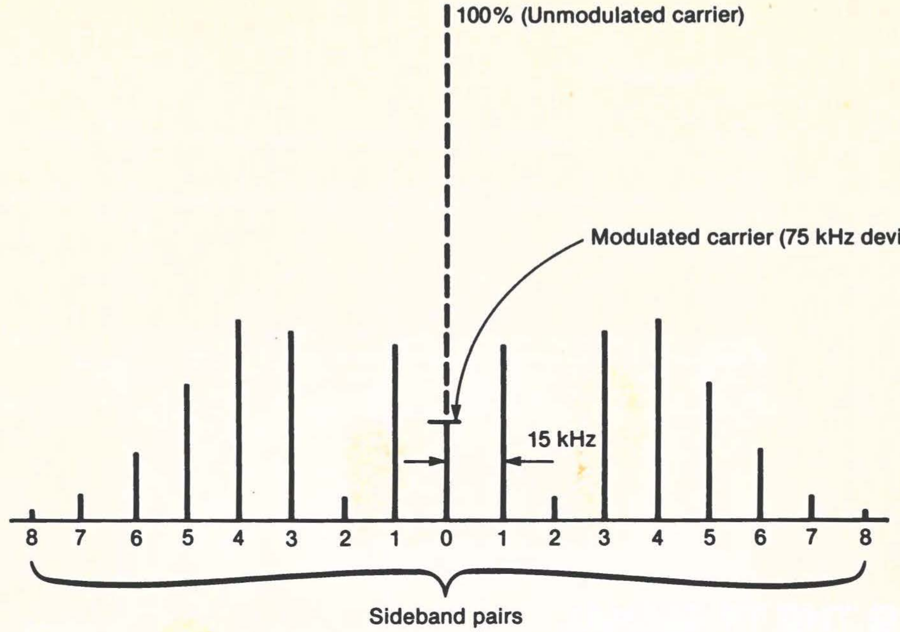


Fig. 11. Spectrum distribution for broadcast FM at maximum deviation with 15 kHz signal.

Frequency modulation is a complex business in terms of the sideband signals that are produced. When a sine wave is bunched up or spread out the resulting departure from the true sinusoidal shape creates sideband components. These are harmonically related to the modulating frequency and extend in both directions from the carrier in infinite numbers. Thus a carrier modulated with a 4 MHz signal produces sideband signals at 4-MHz intervals that extend above and below the carrier. The energy contained in the first, second and third sidebands is not equal but varies in a very complex way according to the deviation and modulating frequency. Fig. 11 shows the distribution of sideband energy for an FM broadcast where maximum deviation is 75 kHz and the highest audio modulation frequency is 15 kHz. In this case most of the energy is grouped in eight sideband pairs at 15 kHz intervals on both sides of the carrier. Note that energy distribution is quite complex. The second sideband pair for example has an amplitude less than 5% of the unmodulated carrier. (The actual prediction of energy distribution involves mathematics beyond the scope of this booklet.) Energy in sidebands higher than the eighth pair is too low to have much effect if lost. Thus the first eight sidebands, in this case, are called the *significant* sidebands.

If eight sideband pairs were needed for the 4 MHz video signal the total bandwidth requirement would be 4 x 16 or 64 MHz! It's a happy fact however, that as modulation frequency rises with respect to peak deviation, the number of significant sideband pairs decreases. The ratio of deviation to modulating frequency is called the *modulation index* and is used to predict the significant sideband pairs.

$$\text{modulation index} = \frac{\text{peak deviation}}{\text{modulating frequency}}$$

In the case of video tape recorders the highest modulating frequency is 4 MHz and peak deviation is less than 4 MHz. This results in a fractional modulation index (0.5 or less usually). In this case the significant energy is concentrated within the deviation range and the first sideband pair. From the standpoint of bandwidth requirements then, video FM is little different from amplitude modulation.

For a broadcast recorder, deviating between 7 and 10 MHz, the first sideband pair is approximately 4 MHz on either side of the center (8.5 MHz), so the significant energy lies between 4.5 and 12.5 MHz.

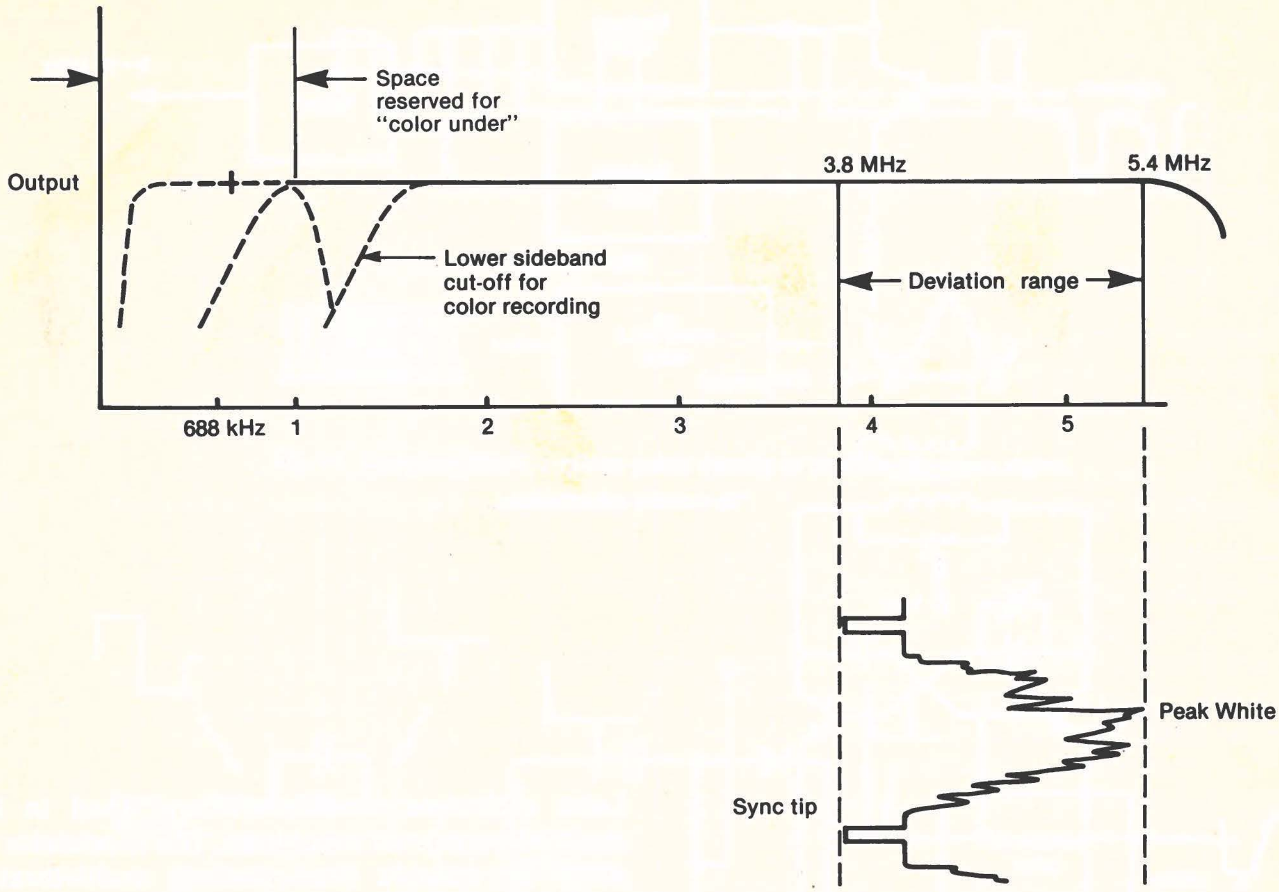


Fig. 12. FM processing in the U-matic system.

Industrial and consumer VTRs make do with less than the maximum luminance bandwidth and handle the color signal as a separate entity. In addition, the upper sideband is sacrificed and only the lower sideband survives the playback process. See Fig. 12. The first lower sideband appears at about 1.1 MHz (considering a maximum deviation frequency of 3.5 MHz).

When color signals are recorded, the spectrum slot between zero and 1 MHz is reserved for direct recording of the narrow band color signal (± 500 kHz or 1 MHz) as will be shown in some detail in later lessons. A high-pass filter is placed at the output of the FM modulator to prevent high order sideband signals from invading the band reserved for the color signal.

Modulation Techniques. In audio FM, which deals with signals that are fundamentally sinusoidal, the modulation voltage causes the carrier to deviate above and below the central carrier. In complex signals like video however, the average axis is constantly changing with scene brightness. For this reason it has become the practice to clamp the tip of sync to whatever d-c level causes the modulator to operate at the low end of the deviation range as shown in Fig. 12. Signal excursions in the white direction then cause an upwards deviation in frequency. Peak amplitude is adjusted so that the peak-white part of the signal drives the modulator to the maximum deviation value (5.4 MHz in the U-matic system, for example). This means that every voltage level from sync tip to peak white corresponds to a particular frequency. Each shade of gray translates into a specific frequency.

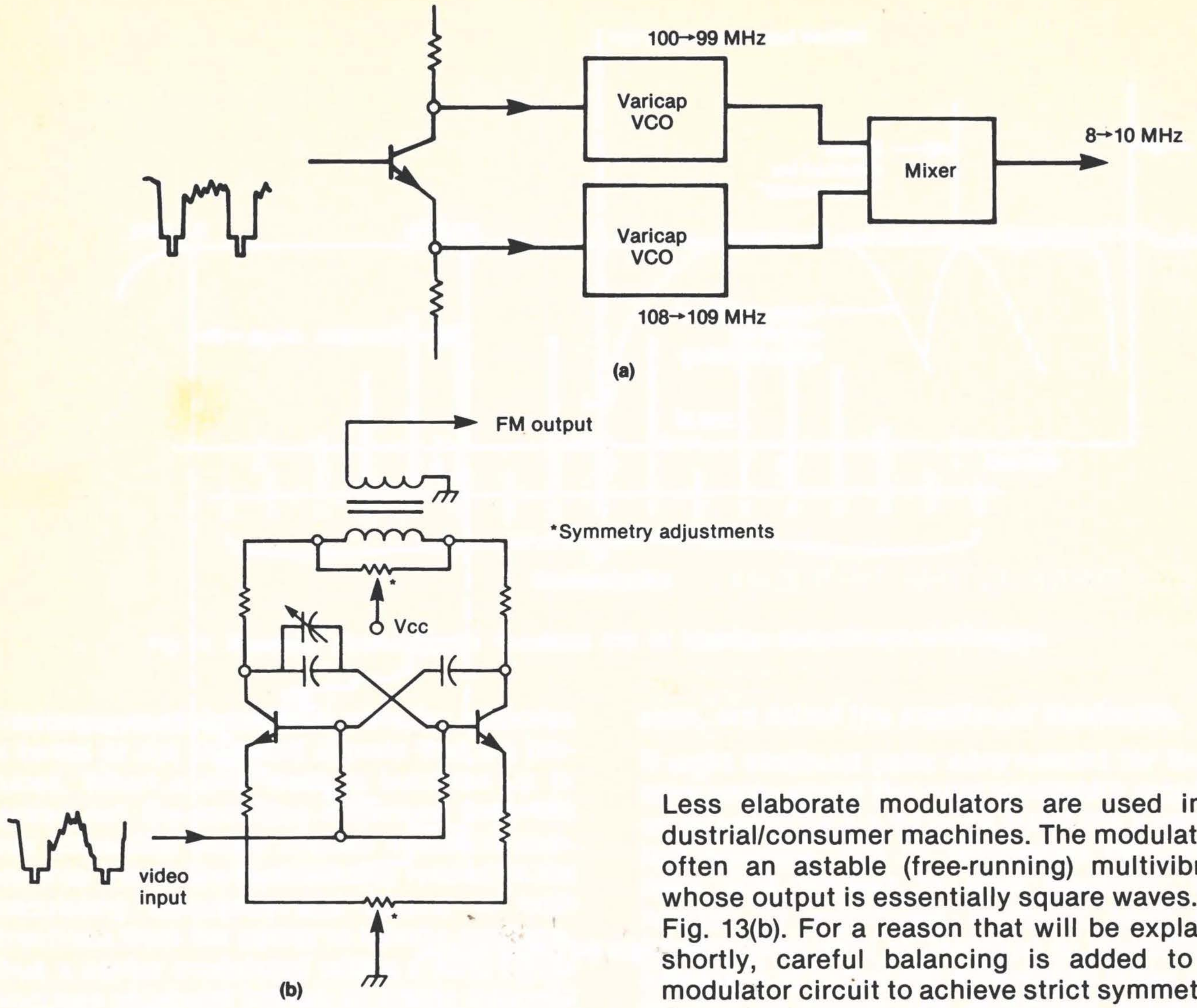


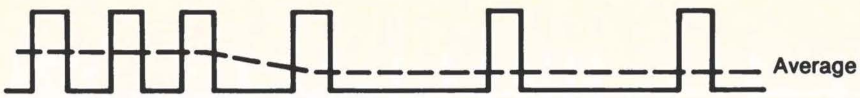
Fig. 13. Basic FM modulators.

Frequency Modulators. The modulators employed in VTRs are voltage controlled oscillators (VCO). In broadcast machines, the VCOs produce sinusoidal FM signals of good spectral purity. One method uses two varicap-controlled high-frequency oscillators operating at about 100 MHz, with a difference frequency of 8 MHz. See Fig. 13(a). Oppositely-phased signals are applied to the varicaps so that one oscillator is driven downwards in frequency, the other upwards. The two signals drive a mixer and the difference signal, varying between 8 and 10 MHz is extracted. The use of two varicaps driven in opposite directions achieves excellent linearity in the voltage/frequency relationship.

Less elaborate modulators are used in industrial/consumer machines. The modulator is often an astable (free-running) multivibrator whose output is essentially square waves. See Fig. 13(b). For a reason that will be explained shortly, careful balancing is added to the modulator circuit to achieve strict symmetry in the output square wave.

Record Amplifiers. An amplifier stage supplies drive to the record head(s). In the FM system drive current is made large enough to just drive the tape into saturation in both directions (positive and negative peaks of the FM signal current). Some degree of pre-equalization may also be applied in the record amplifier to compensate for the relatively low output in playback at the low end of the playback spectrum.

Playback Processing. A low-noise preamp raises playback signal to the amplitude needed to drive a series of limiters. The limiters remove most of the amplitude variations caused by mechanical tracking errors (when the heads stray off the recorded tracks), and dropout. Constant amplitude FM signals are then applied to the demodulator. Demodu-



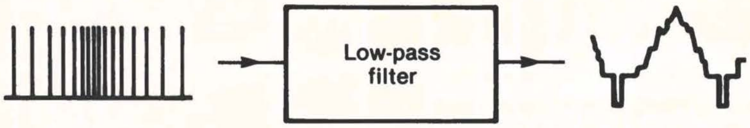


Fig. 14. Low-pass filter integrates pulse density to produce the video signal.

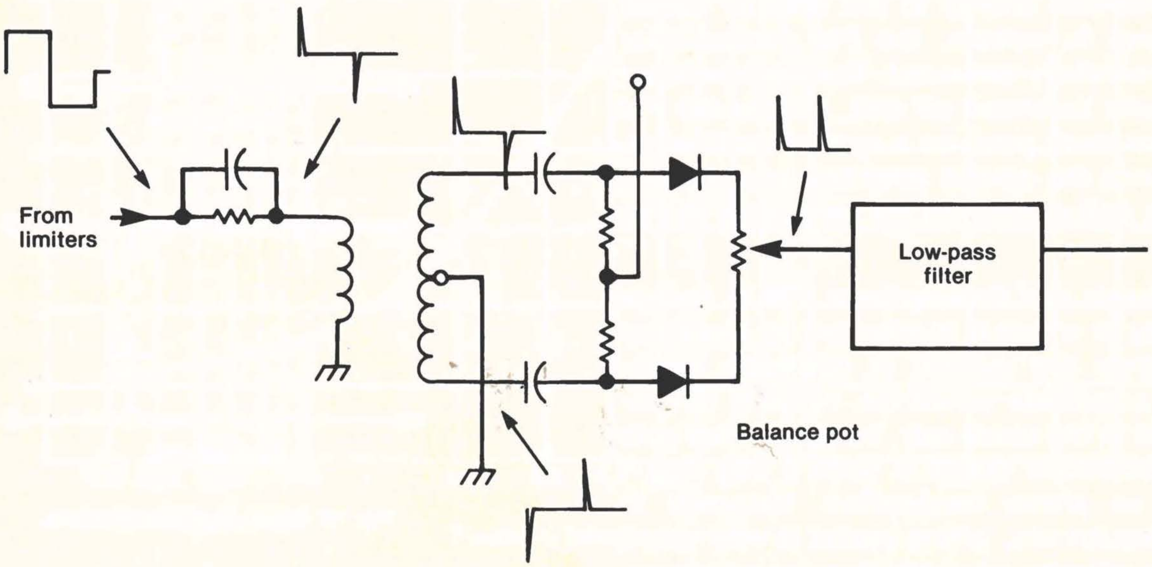


Fig. 15. Simple pulse-density detector acts to double carrier frequency.

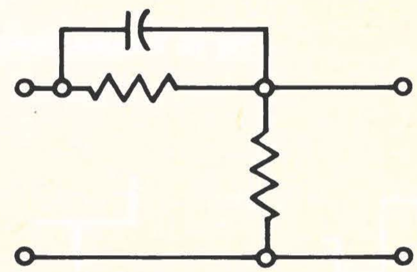
lators used in video tape recorders are of the pulse-count or pulse-density type. By various methods, each cycle of the FM wave is converted into a narrow pulse of accurately-controlled duration. These pulses are then integrated by a low-pass filter. The filter in effect averages the voltage resulting from variations in pulse density to reconstruct the original video modulator. See Fig. 14.

Fig. 15 shows a very simple FM demodulator found in early SONY machines (CV). The input square waves from the limiters are differentiated by an RC network to form narrow positive and negative voltage spikes. A transformer coupled full-wave rectifier selects only the positive pulses to be fed to the low-pass filter. You will recognize the rectifier circuit as the same type of circuit used in full-wave power supplies. In addition, the full-wave circuit acts to double the input frequency. This is the case here; there are two positive spikes for each input wave and the carrier frequency (the ripple frequency at the output) is effectively doubled.

Frequency doubling is important in industrial/consumer machines because the low end of the deviation range is within, or very close to, the high end of the video passband. For example, in the U-matic system the low end of the FM deviation is 3.8 MHz.

For the frequency doubling to be complete, and no residual energy at the original carrier frequencies to remain, the FM demodulator must be carefully balanced. The limiters must be carefully balanced as well. Finally the FM modulator must produce a symmetrical waveform. Hence the careful attention to symmetry adjusting components in the modulator of Fig. 13(b).

Pre-emphasis and De-emphasis. FM is unique in the way in which it is affected by electrical noise. Since the system is relatively insensitive to amplitude variations, noise is not encountered in the usual way. Instead, noise acts to alter waveform shape in such a way that it appears as phase modulation. Naturally at higher frequencies, where period is very short, the effect of noise on phase is more pronounced. The result is that FM system noise varies directly with frequency. To counter this effect a low-pass filter is added following the demodulator in the playback circuits. The effect of this filter is to reduce high-frequency noise. Of course high-frequency video signals are attenuated to the same degree. However, high frequency signals are boosted prior to record by a filter that precedes the FM modulator. This filter is designed to reverse the action of the low-pass filter in the playback circuits. This system of record boost and playback cut is called pre-emphasis and de-emphasis, respectively. It is used in all FM systems, including broadcast audio FM.


Pre-emphasis

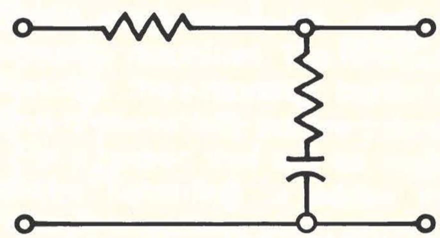
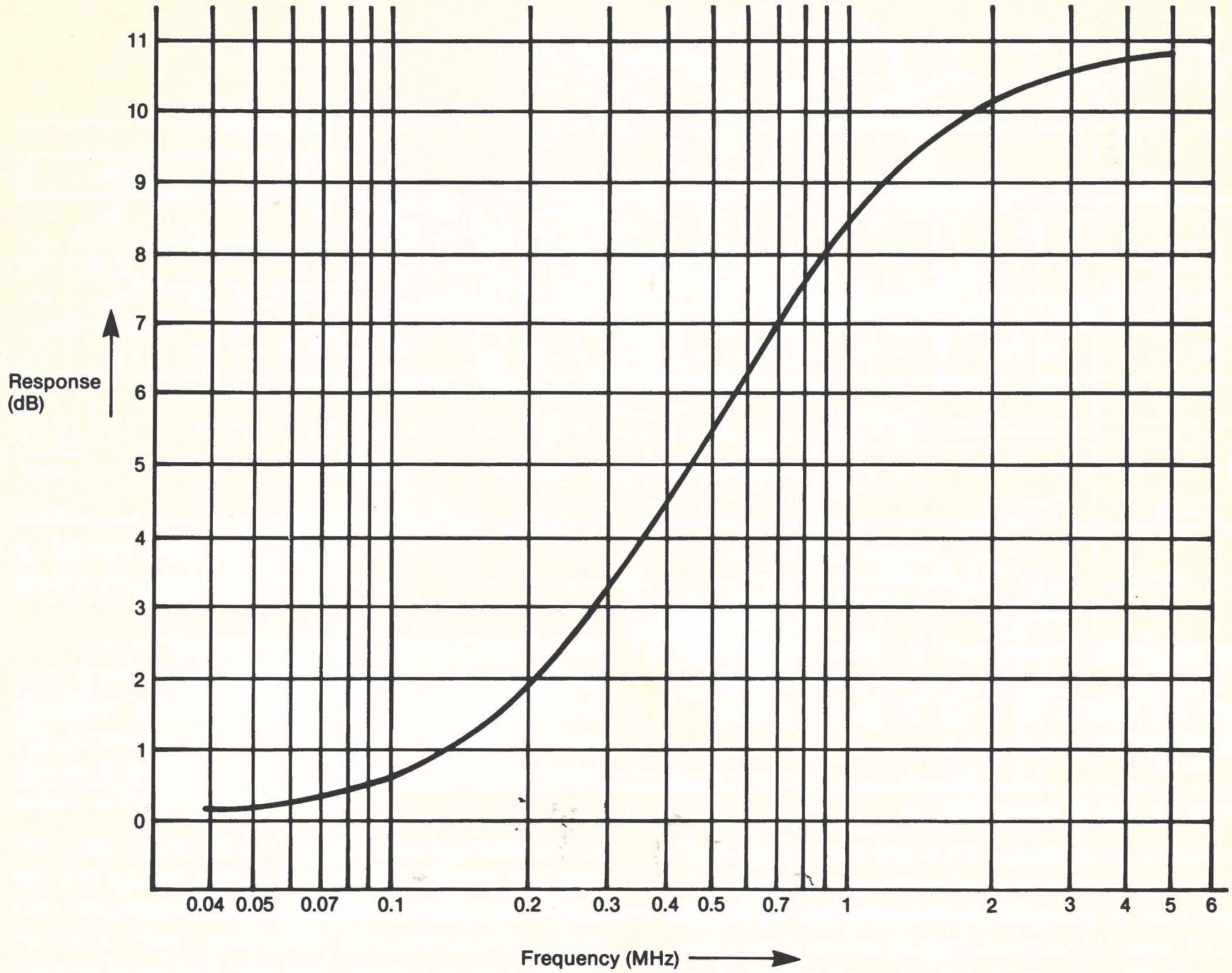
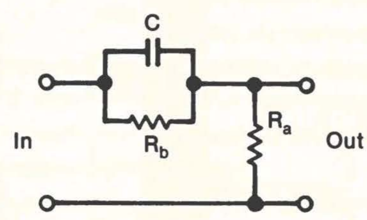

De-emphasis

Fig. 16. Basic emphasis networks.

Fig. 16 shows the form of simle pre-emphasis and de-emphasis networks. Fig. 17 shows the network and response curve employed in the record circuits of the U-matic system. Since pre-emphasis is part of the record-signal specification the constants of the network are part of the system standard. A machine made to that standard must include a pre-emphasis network that produces the same frequency characteristic as the standard "model". The actual form taken by the networks in use varies considerably and may be difficult to find on an actual schematic. Pre-emphasis and de-emphasis correction is often part of negative feedback loops. See Fig. 18.





$T = C\ R_b = 0.6\ \mu sec \pm 0.5\ \mu sec$

$X = R_b/R_a = 2.5 \pm 0.3$

Fig. 17. U-matic pre-emphasis specifications.

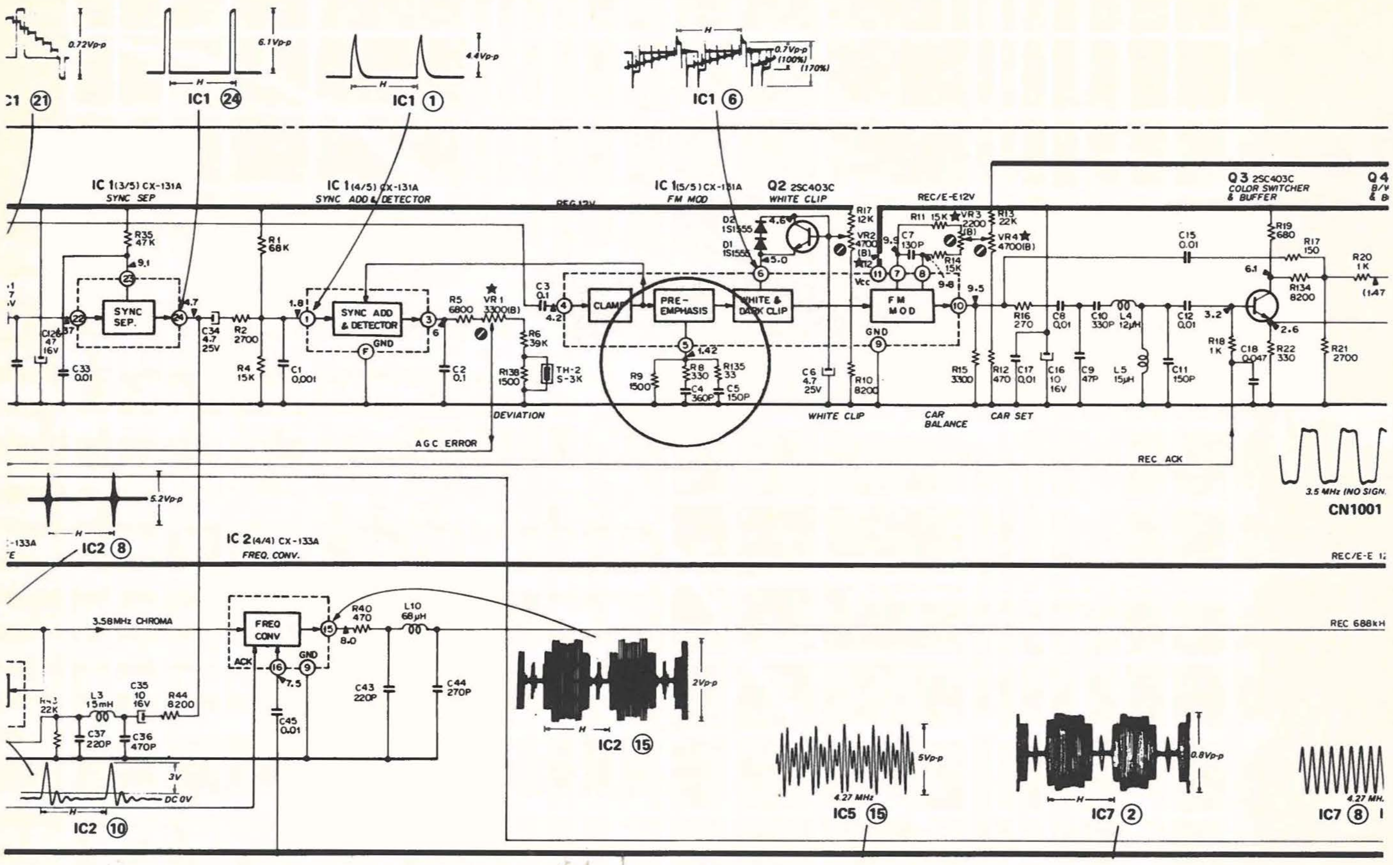


Fig. 18. Pre-emphasis in the form of a low-pass filter in a negative feedback loop.

FM Processing Summary. Here are some important aspects of FM processing in video tape recorders.

1. In broadcast-quality recorders, the entire video bandwidth of 4.2 MHz, including the multiplexed color signal is recorded as a frequency-modulated signal.
2. Most of the energy contained in the FM signal is distributed within the deviation range and the first sideband pair.
3. Both sidebands are recorded and reclaimed in broadcast quality recorders; however, a large part of the upper sideband is sacrificed in industrial and consumer VTRs.
4. The top of the FM passband in industrial/consumer machines is slightly above maximum deviation range. (About 5.4 MHz for the U-matic and 5.1 MHz for Betamax.)
5. Sync tip is clamped to the d-c level that makes the FM modulator operate at the low end of the deviation range.
6. Signal excursions in the white direction cause upward deviation in frequency.
7. Peak white corresponds to the top of the deviation range.
8. Pre-emphasis, a boost of high-video frequencies, is applied to the video signal prior to frequency modulation.
9. De-emphasis, to equalize the effects of pre-emphasis and reduce noise is applied to the playback video signal following FM demodulation.

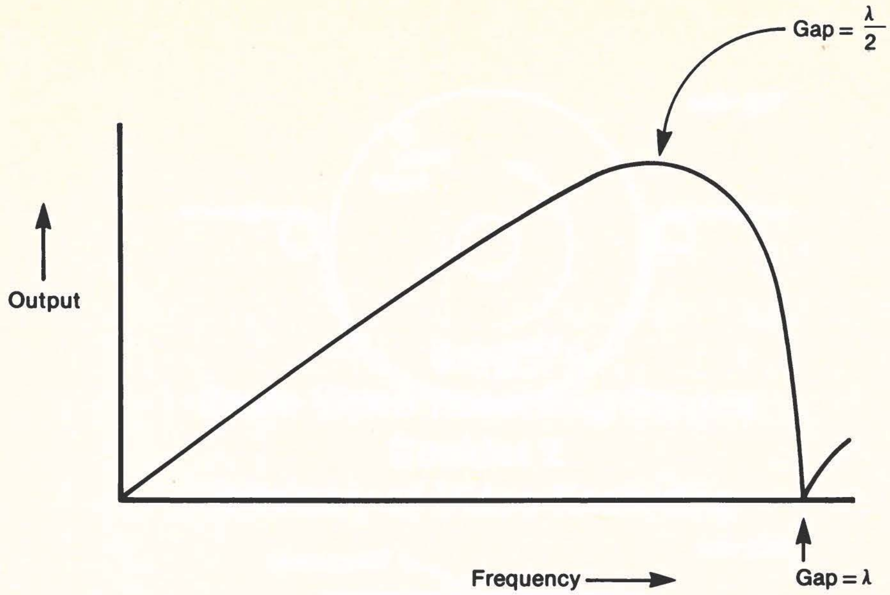


Fig. 19. Playback characteristics.

4. WRITING SPEED REQUIREMENTS

The use of frequency modulation pushes the high-frequency requirements of the tape recorder beyond the original video passband. For example, the U-matic must record signals above 5.4 MHz although the luminance bandwidth is less than 4 MHz.

We can make some rough approximations of writing speed needs by making use of the relation between wavelength and head gap. Fig. 19 reviews the playback characteristic that results from the fact that output rises steadily at 6 dB per octave. The peak occurs near the point where head gap straddles a half wavelength of recorded signal (head gap is twice the recorded wavelength). The curve then descends into a null at which head gap straddles one wavelength.

The gap in the U-matic video head is 850 millimicrons (0.85 microns), and the top of the deviation range is 5.4 MHz. To put playback output at the peak of the curve in Fig. 19, wavelength at the highest frequency to be recorded should be twice the head gap, in this case 2 x 0.85 = 1.7 microns = 1.7 x 10^{-6} meters. Solving the wavelength formula for speed we get:

$$\lambda = \frac{\text{writing speed}}{\text{Frequency}}$$

writing speed = Frequency x wavelength

Substituting U-matic values:

writing speed = 5.4 x 10^6 cycles per second x 1.7 x 10^{-6} meters
= 5.4 x 1.7
= 9.18 meters per second

This gives us a ball-park figure only. Other considerations are manufacturing tolerances, how much of the lower FM sideband is reclaimed, and other forms of high-frequency loss. The actual writing speed in the U-matic is 10.3 meters per second.

The *Betamax* head gap is only 600 millimicrons thick. (That's equivalent to a wavelength of red light.) The system plays back signals that extend up to 5.1 MHz. Putting these values into our formula gives an approximate writing speed of:

writing speed = 5.1 x 10^{+6} cycles per second x (2 x 0.6) x 10^{-6} meters
= 5.1 x 1.2
= 6.72 meters per second

Here again, actual writing speed is somewhat higher — 6.9 meters per second.

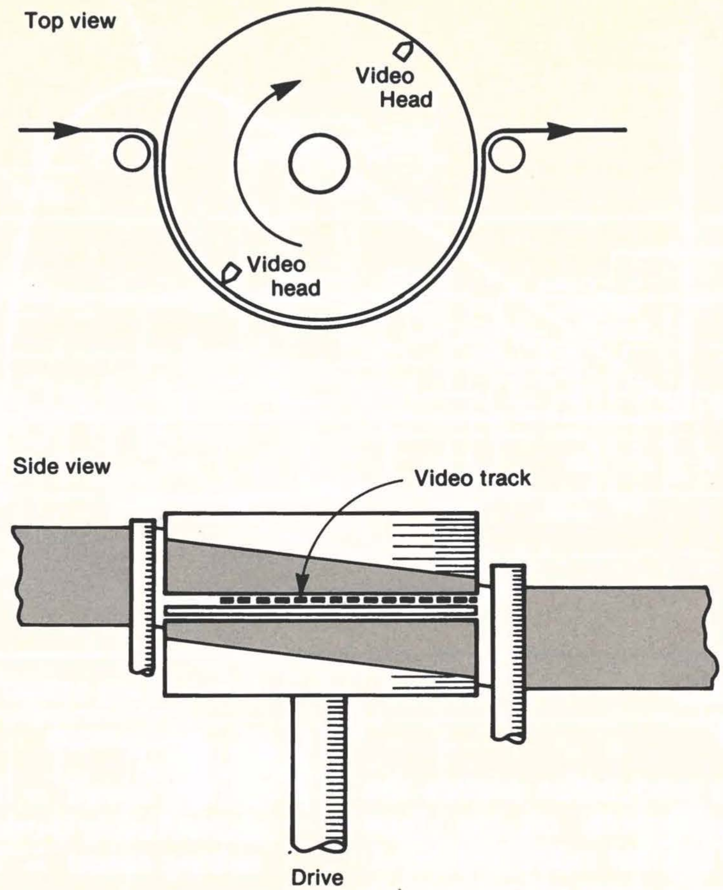


Fig. 20. Basic scanner.

Rotary Head Systems. Although some early attempts were made to obtain the required writing speed using stationary heads, the only systems that were ever actually put into production made use of moving (rotating) video heads. RCA demonstrated a prototype stationary-head machine in the early 1950s. It moved tape past the stationary heads at the amazing speed of about 17 feet per second. However, recording time for the relatively large 19-inch reels was necessarily short. During the development of VTRs many methods have evolved that make use of one or more video heads that revolve in rotating "scanners" so that the heads cross the relatively slow-moving tape at an angle. The various systems will be treated in the next lesson, but the basic idea is shown in Fig. 20. Here a pair of video heads is mounted on a disc that rotates between stationary upper and lower cylinders. Tape flows around the cylinder at an angle to the plane in which the disc rotates. Thus, each video head scans (crosses) the tape from one edge to the other. During each "swipe" a portion of the video signal is recorded. Tape motion is slow compared to head speed, but the movement of tape establishes the "pitch" or spacing between adjacent tracks.

In the next lesson, you will learn: how various single and multiple-head scanners are built; segmented and full-field recording; the mechanical and electrical factors that must be considered in recording and playing back a continuous video signal despite the fact that the heads must leave the tape at regular intervals.

Take the time now to complete the self-test at the back of this booklet.

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Basic Video Recording Course
Booklet 2
Glossary of Video Recording

Aspect ratio—Ratio of picture width to picture height.

Blanking—The process of turning off the scanning electron gun of a CRT during retrace periods so that no image is made.

Bandwidth—The range of frequencies over which output remains uniform, as measured between the frequency where power drops to half (3 dB in power, 6 dB in voltage).

Carrier—In a modulating system, the waveform on which the signal information is impressed.

De-emphasis—The process by which previously boosted frequencies are attenuated in order to produce the original signal, but with less noise.

Demodulator—A device which recovers the modulating information signal from a modulated carrier.

Deviation—The excursion of an FM carrier frequency from the original carrier frequency. This excursion represents the information signal.

Equalizing pulses—Pulses at twice the line frequency just before and just after the vertical sync pulses, which retain sync during blanking periods.

Factor 80—A rule of thumb relation between lines of resolution to bandwidth; Bandwidth X 80 = #lines of resolution.

Field rate—The rate (60 Hz) at which a field or half a picture (262.5 lines) appears on the video screen.

Frame rate—The rate (30 Hz) at which a frame or a complete picture (525 lines) appears on the video screen.

Frequency Modulation—The modulation technique whereby the frequency of a wave is varied from the original carrier frequency by a signal.

Horizontal blanking—The off-period of the electron gun during horizontal retrace (4.76 μsec for horizontal sync; blanking, 10.4 μsec).

Horizontal resolution—The number of individual picture elements which can be distinguished across a horizontal scanning line.

Interlace—The technique of presenting half of the lines composing a picture, or a field, alternately with the other half so that a complete picture, or frame of 525 lines, occurs 30 times per second.

Limiter—An electronic device which outputs a signal of constant amplitude even though the input signal's amplitude varies. When used in FM demodulation, successive limiters will output a constant amplitude pulse train by driving all signal amplifiers in the chain into saturation.

Modulator—A device which varies a characteristic of a carrier (either amplitude, frequency or phase) as a function of an information signal.

Persistence of Vision—The image lag effect of the human eye, due to the slow response to rapidly changing visual stimuli.

Pre-emphasis—The process of boosting frequencies in a signal processing system, to compensate for later frequency roll-off; reduced noise being the result.

Raster—The number (525) of horizontal lines which make up a complete video picture or frame.

Subcarrier—A second modulated carrier on which additional information (color, balance) about the main signal is impressed.

Sync tip—The lowest level in a complex video waveform which corresponds to the horizontal scanning synchronizing signal.

Utilization ratio—The ratio (0.7) of lines in a raster which contribute to the vertical resolution.

Vertical blanking—The off-period of the video electron gun during vertical retrace. (Vertical sync is 3 horizontal lines long; blanking, 21).

Vertical resolution—The number of horizontal lines stacked one on another, that can be discerned by the average viewer.

Visual acuity—The ability to resolve small picture details such as shape and color.

Writing speed—The relative speed between the magnetic record head and the tape surface.

SONY
BASIC VIDEO RECORDING COURSE
SELF TEST NO. 2
VIDEO RECORDING

(Circle or fill in your answer.)

1. Video bandwidth needed to provide a 260-line resolution is approximately: (a) 4.2 MHz; (b) 5.4 MHz; (c) 2.5 MHz; (d) 3.25 MHz.
2. The number of raster lines in one TV field is: (a) 320; (b) 525; (c) 262½; (d) 1000.
3. The bandwidth of demodulated color signals in a modern TV set is about: (a) 500 kHz; (b) 1.2 MHz; (c) 3.58 MHz; (d) 4.2 MHz.
4. The number of equalizing pulses preceding the start of the vertical sync pulse is: (a) 3; (b) 6; (c) 12; (d) 18.
5. In FM video recording, energy is distributed over the deviation range and: (a) one sideband pair; (b) 3 sideband pairs; (c) 5 sideband pairs; (d) 8 sideband pairs.
6. The video level associated with the low end of the deviation range is: (a) blanking; (b) peak white; (c) 50% APL; (d) sync tip.
7. In FM video recording, the amplitude of the signal applied to the record heads is: (a) just large enough to drive the tape into saturation; (b) kept below the value that will saturate tape; (c) just above record noise level; (d) adjusted for best amplitude linearity.
8. FM demodulators used in industrial VTRs: (a) are ratio detectors; (b) Foster-Seely discriminators; (c) half-wave rectifiers; (d) pulse-density detectors that double ripple frequency.
9. The pre-emphasis network is a: (a) high-pass filter; (b) band-pass filter; (c) low-pass filter; (d) notch filter.
10. The de-emphasis network is placed in the circuitry: (a) ahead of the FM modulator; (b) between the limiters and the FM demodulator; (c) following the FM demodulator; (d) in the playback preamp.

11. Low frequency response in the FM system extends to: (a) 60 Hz; (b) 30 Hz; (c) 10 Hz; (d) zero.
12. The signal in the playback preamp for an industrial/consumer VTR covers a frequency range of: (a) the deviation range only; (b) the deviation range and both upper and lower sidebands; (c) the deviation range and lower sideband; (d) the deviation range and upper sideband.
13. The duration of vertical blanking is: (a) 9 lines; (b) 63.5 microseconds; (c) 21 lines; (d) 42 lines.
14. A frequency of 5.4 MHz in the U-matic system corresponds to: (a) 3.5 MHz bandwidth; (b) 50% APL; (c) sync tip; (d) peak white.
15. Pre-emphasis and de-emphasis are employed to: (a) widen bandwidth; (b) maintain gamma correction; (c) improve playback S/N; (d) permit recording of the multiplexed color signal.
16. A typical video recording head has a gap thickness of: (a) 800 microns; (b) 80 microns; (c) 0.8 microns; (d) 80 millimicrons.
17. A writing speed for an industrial VTR could be: (a) 7.5 inches per second; (b) 10 meters per second; (c) 1 meter per second; (d) 100 meters per second.
18. The first null in the playback resonse of a recorder occurs when recorded wavelength: (a) equals gap thickness; (b) is twice gap thickness; (c) is half gap thickness; (d) is four times gap thickness.
19. A VTR with a video head gap of 5 microns must have a writing speed of __________ to reclaim signal at 6 MHz.
20. To reclaim a signal of 5.5 MHz in a machine with a video head gap of 0.5 microns requires a writing speed of __________.

Answers:

1.	(d)	6.	(d)	11.	(d)	16.	(c)
2.	(c)	7.	(a)	12.	(c)	17.	(b)
3.	(a)	8.	(d)	13.	(c)	18.	(a)
4.	(b)	9.	(a)	14.	(d)	19.	60 meters per second
5.	(a)	10.	(c)	15.	(c)	20.	5.5 meters per second

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Published by
VIDEO TECHNICAL INFORMATION
700 WEST ARTESIA BLVD., COMPTON, CA 90220